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ABSTRACT

The various systems for communicating with manned and unmanned spacecraft are described in this pamphlet written for general science students. The pamphlet is one of the NASA Facts Science Series (each of which consists of four pages) and is designed to fit in the standard size three-ring notebook. Review questions, suggested activities, and references are included. (PR)

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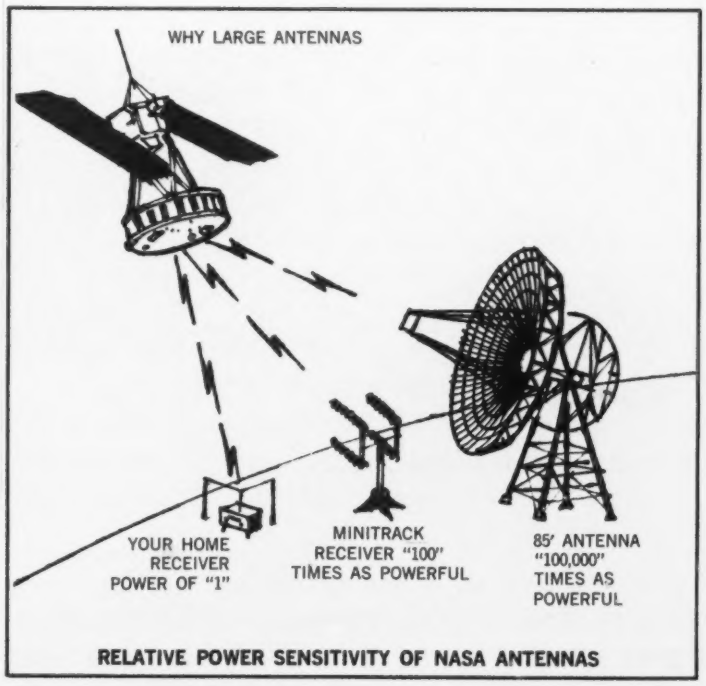
Spacecraft Tracking and Communication


WHY LARGE ANTENNAS
YOUR HOME RECEIVER POWER OF "1"
MINITRACK RECEIVER "100" TIMES AS POWERFUL
85' ANTENNA "100,000" TIMES AS POWERFUL

RELATIVE POWER SENSITIVITY OF NASA ANTENNAS

Spacecraft can operate far from earth. Their electronic signals must be caught by highly sensitive ears. This picture illustrates the relative power of various antennas.

STADAN . . . NASCOM . . . SCAMA II . . . These strange words have an unearthly sound. This is appropriate, for all are letter groupings identifying electronic systems of communications for the space age. They are bridges between men and women of science on earth and manned and unmanned spacecraft hundreds or thousands of miles away in airless space.

The National Aeronautics and Space Administration has developed three such bridges: for unmanned satellites, for manned flights, and for probes into the deep space of the moon and the planets.

STADAN

The communications network for tracking and receiving information from unmanned satellites is called STADAN for **S**pace **T**racking **A**nd **D**ata **A**cquisition **N**etwork. It is operated by NASA's Goddard Space Flight Center, at Greenbelt, Maryland, near Washington, D. C. The network includes twenty-six stations strategically located around the world (See map on page 2). Fourteen are electronic, and communicate with spacecraft by radio. Twelve are optical, and photograph spacecraft in flight against a background of stars.

The transmittal of information to and from an unmanned satellite is exacting and complicated. Since no human is aboard to report scientific findings, all information must be transmitted to and from a satellite on a signal from the earth station. To accomplish this task, STADAN stations are equipped with very sensitive "ears" or antennas. These antennas, because of their specialized missions, vary in shape and size. Some are long and slender and some resemble giant corkscrews. Others are big and saucer-shaped.

The antennas receive radio signals as a satellite passes overhead. Critical information may be transmitted immediately, but in general the signals are stored on tape and then shipped to Goddard. There the tapes are run through computers for interpretation and comparison with other data so the scientist may know what happened in space, where it happened, and precisely when.

The Center, on a weekly basis, receives about 50 miles of magnetic tape containing information about the space environment. If this information were converted to narrative form it would amount to approximately 170 million words, enough to fill 180 encyclopedia volumes every day.

Scheduling orbital passes for each station in the network is complicated and precise. STADAN is responsible for tracking and monitoring more than 30 satellites daily.

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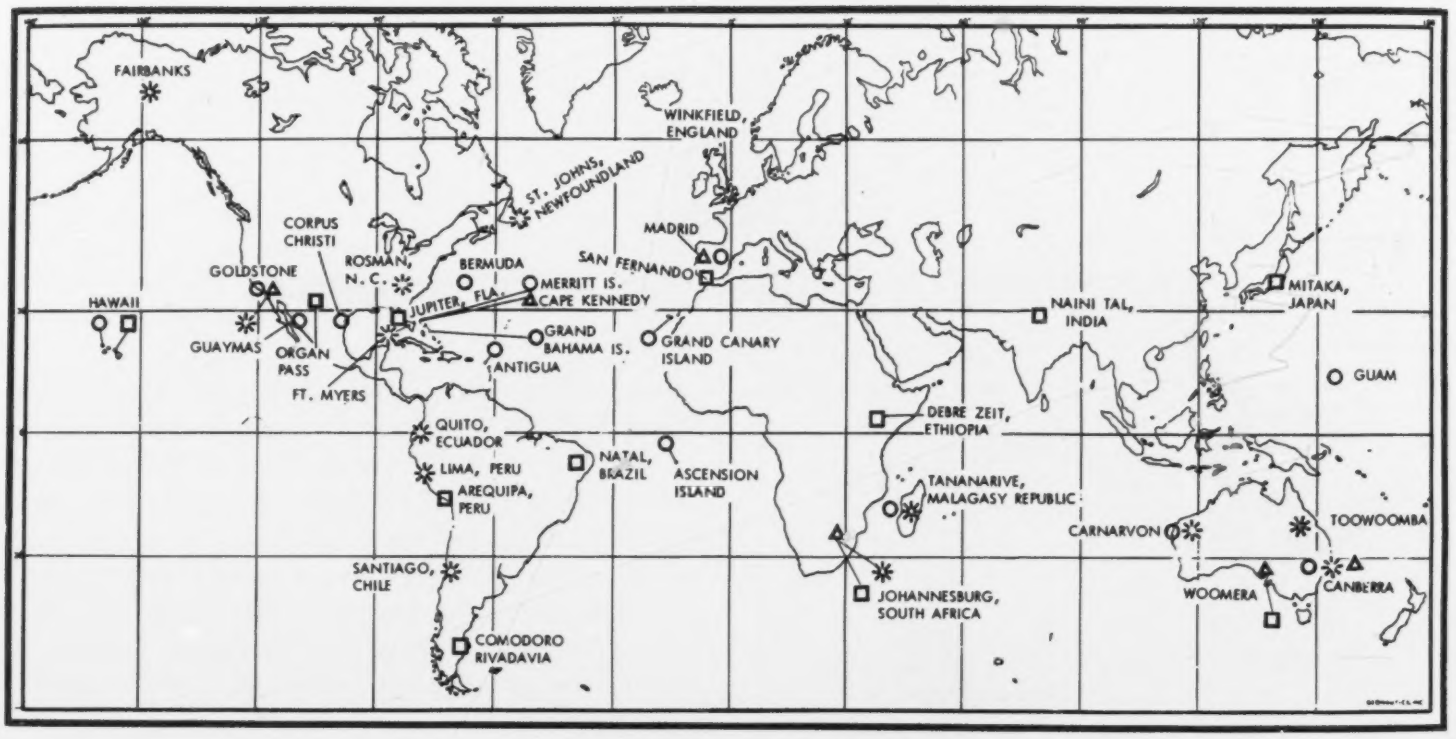

NASA TRACKING FACILITIES

○ MANNED SPACE FLIGHT NETWORK ✲ SATELLITE TRACKING AND DATA ACQUISITION NETWORK △ DEEP SPACE INSTRUMENTATION FACILITIES □ OPTICAL TRACKING NETWORK

TRACKING

Tracking provides the information for continuously reporting the location of a satellite, a probe that is going deep into interplanetary space, or of a small rocket that will penetrate space on an up-down path, perhaps only a few hundred miles. (See map for location of sounding rocket, applications technology satellite, electronic and optical stations.)

Location is important for the scientist, because he has to know precisely where the spacecraft is at a particular point in time. With this information, he can correlate an event measured by the spacecraft with, for example, its position relative to the sun, the moon, or earth. Also he has to know its position in order to send it guidance information; to send it commands to make observations; transmit data; to assure safety; or possibly change its flight plan.

Several systems for tracking orbiting satellites have evolved within the last few years. The two main techniques used by NASA for tracking unmanned satellites are the world-wide Minitrack System and the Range and Range Rate System.

Minitrack is an angle measuring system. The name is derived from **Mini**mum Weight **Track**ing. It uses a radio interferometer which receives a radio signal from the spacecraft at two different points, and measures the angle from the spacecraft and the difference in time of arrival of the signals to determine position. When Minitrack was developed spacecraft missions were planned for low circular orbits around earth. As technology advanced, spacecraft were launched also on highly elliptical orbits extending hundreds of thousands of miles into deep space. The Minitrack angle measuring system remains the basic system of NASA's low orbiting Space Tracking and Data Acquisition Network, but is not adequate for the great distances of elliptical orbits because at apogee the spacecraft travels with a very slight change in angle from earth. Thus, a new method of tracking was needed for these missions and the system selected was called Range and Range Rate.

The Range and Range Rate System is a high-precision spacecraft tracking system capable of accurately determining the range (line of direction) and radial (moving along a radius) velocity of a

spacecraft from near-earth orbits of about 500 miles altitude outward to hundreds of thousands of miles.

TELEMETRY

Telemetry is the science of taking measurements from a distance. The word telemetry is derived from two Greek words, tele and metron (**tele** means far-off or distant and **metron** means to measure). Contrary to popular belief, telemetry is not a young science. As far back as 1885, patents were issued in the United States for an electrical telemetering system. However, real advances were not made until after World War II. Then, high-speed aircraft and rockets began to demand many channels of information for their flight testing.

In space flight, radio telemetry is used to measure and report everything from an astronaut's blood pressure and heart beat to the strength of the earth's magnetic field.

What happens is this; instruments inside a spacecraft called sensors react to an event. This information is transformed into a coded electrical signal and transmitted to earth.

DATA PROCESSING

Once a satellite has been orbited it collects information about space, and sends it to NASA ground stations. There it is recorded and sent to the Goddard Space Flight Center where it is processed into meaningful information.

Satellites broadcast tone signals. When these are received by NASA earth stations the signals are recorded on tape for decoding and study. First, the taped tone signals are processed by computers and converted into digital form. The range of numbers is then compiled as information for scientific study and analysis.

NASCOM

For a successful space mission of any kind, fast, reliable communications are a necessity. Spacecraft now travel thousands of miles from earth. To reach the moon the spacecraft must go 240,000 miles from earth. In earth orbit, the satellite may travel more than 17,000 miles per hour and circle the world about every 100 minutes.

To enable program scientists and mission directors to keep in touch with each other and in contact with specific spacecraft missions, NASA operates a worldwide communications network called NASCOM (NASA Communications network). Its hub of activity is also at Goddard. NASCOM provides high-speed ground communications support for manned, unmanned, and deep space missions. It links 89 stations, including 34 overseas points, with teletype, voice, and data communications. Its circuits and terminals span 100,000 route miles and 500,000 circuit miles. NASCOM uses commercial and government land-line circuits, ocean cable, radio, and communications satellites and includes sub-switching centers in London, Honolulu and Canberra, Australia.

Heart of this system is the communications processor which uses a digital computer for receiving, examining, storing, cueing, and transmitting messages electronically at very high speeds. This system is so efficient that the average time for processing a message (for an unmanned satellite) for transmission to a destination thousands of miles away is about 5.8 seconds.

SCAMA

Voice communications of NASA's entire communications network are also controlled from Goddard. A ground controller can reach an astronaut in space in less time than it takes to dial your telephone for a local call.

This system is called SCAMA II (**S**tation **C**onfer encing **A**nd **M**onitoring **A**rrangement). With it both point-to-point connections and conference arrangements are possible. All lines can be connected into one conference without loss of quality. The SCAMA operator can add or remove conferees. He also controls which of the conferees can talk and which can listen only.

DEEP SPACE NETWORK

The Deep Space Network supports NASA's lunar and planetary missions. Extremely powerful and very sensitive 85-foot diameter paraboloidal antennas are used to receive data from spacecraft, determine their location in space and command them to maneuver in space. A new antenna, 210-foot in diameter, is the largest fully steerable space antenna in the world.

Deep Space Network stations are located at 120° intervals of longitude apart, so that with three stations around the world, one will always have a line-

of-sight communication with the spacecraft as the earth rotates (see map).

The network is operated for NASA by the Jet Propulsion Laboratory of the California Institute of Technology. Control center for the network is maintained by JPL at Pasadena, California. The DSN, used for operational control and data transmission between these stations, is a part of the larger communications net (NASCOM) linking all of the NASA stations around the world.

APOLLO NETWORK

A special Manned Space Flight Network to support Project Apollo (three-man Lunar Flight Mission) is now being established. The network will comprise 14 land stations, five ships, eight instrumented aircraft, and cable, telephone, teletype and radio circuits with their land and satellite terminals to link the stations with mission control centers.

Eleven land stations are equipped with 30-foot-diameter antennas for support during launch and earth orbit. Six are former Gemini sites—Bermuda, Canary Island, Carnarvon (Australia), Hawaii, Guaymas (Mexico), Corpus Christi—modified for Apollo. Five are new—Merritt Island (Florida—at the Kennedy Space Center), Grand Bahama Island (transportable), Antigua, Ascension Island and Guam.

Three new facilities at Madrid, Spain; Canberra, Australia; and Goldstone, California equipped with 85-foot-diameter antennas will support the lunar phase. Deep Space Network 85-foot antennas already at these sites are being augmented for Apollo.

Five instrumented ships will provide reliable communications over broad ocean areas where no land stations exist. The USNS Vanguard stationed in the Atlantic will support Apollo insertion into earth orbit. USNS Mercury and Redstone will support injection into lunar trajectory, the Mercury stationed in the west Pacific and the Redstone in the Pacific or the Indian Ocean. USNS Watertown and Huntsville will support Apollo reentry, the first stationed near Hawaii, the second near Samoa. Vanguard may also support reentry. Vanguard, Redstone and Mercury will maintain circuits with communications satellites over the Atlantic and Pacific.

Eight instrumented aircraft will support voice and telemetry communications during injection to lunar trajectory and during reentry.

QUESTIONS:

1. How is information received from an unmanned satellite? How is the information made useful?
2. What is the difference between Minitrack and Range and Range Rate tracking systems?
3. What is telemetry? How does it work?

ACTIVITIES:

1. To transform sound vibrations into a continuous flow pattern of light, cut both ends out of a small tin can and stretch part of a rubber balloon over one end, fastening it with an elastic band. Glue a small piece of mirror on the balloon, halfway between the edge and the center. Shine a strong light on the mirror to reflect on the balloon, halfway between the edge and the center. Shine a strong light on the mirror so that it makes a spot on the wall or ceiling. Press the open end of the can against your mouth and say words with varying sounds. Notice how the spot of light on the wall or ceiling vibrates, making different patterns for different sounds or wards. If a moving, photographic recording tape were placed in back of the moving spot, it would record the sounds as a continuous fluctuating line.

Reference: Builband, G. T., *What is Cybernetics?* New York: Grove, 1960

2. To visualize the way in which high-frequency radio waves can be transmitted great distances, hold a comb so that the rays from the sun or from a bright light (for example, the light from a slide or movie projector) shine through the comb's teeth and fall on a sheet of paper lying flat. Place a mirror diagonally in the path of the beam of light. Notice how the beams are reflected and how the angles change as the mirror is moved.

Reference: *Countdown to Tomorrow,* American Telephone and Telegraph Co.

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